Flash finder in FD2-VD: TDR sample study

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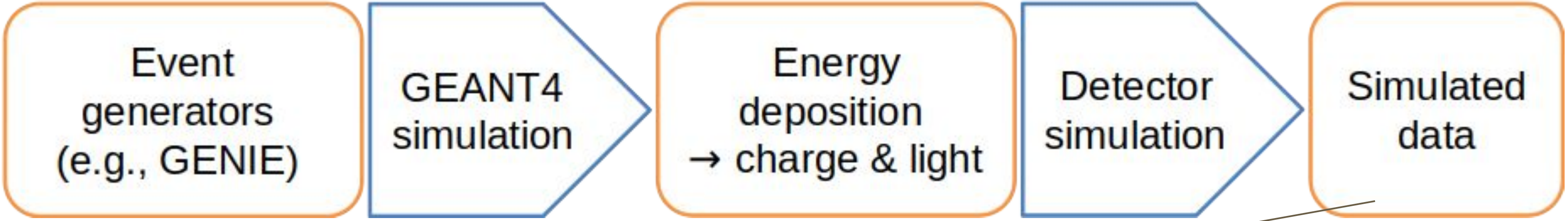
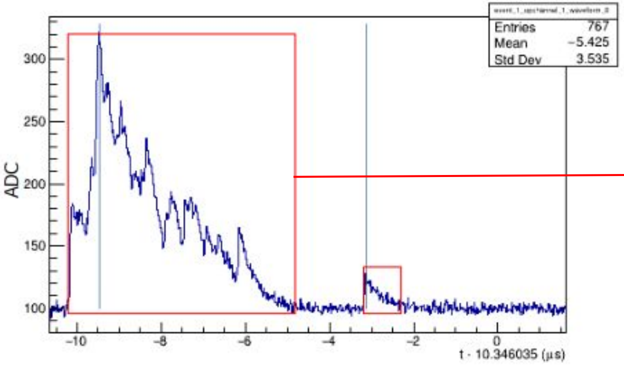
Scintillation light simulation



Example of an optical waveform



hit finding:
searches for peaks on individual waveforms channel-by-channel, identifying the time and the total amount of PEs

Position reconstruction analyzer module

- Position reconstruction → OpFlashFinder algorithm (LarSoft)
- Objective: generate *flashes*, which are clusterings of optical hits related in time and space, aiming towards matching together points that have the same event origin
- Finally, use the PDS and charge info to accurately locate and characterize the flash

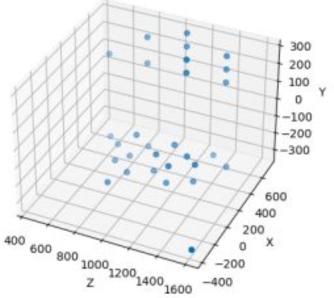
So, step by step:

Simulation (generates a .root file) → Flash finder (.fcl that generates the flashes)

↓

vdflashmatch (.fcl that organizes the information in trees and generates a .root file) → Final .root file for analysis

Creating flashes: how does it work?



Hits for example SN events

Image from P. Barham

OpHit vector (contains the hits in the detectors, per event)

Time

First entry, grabs peak time and time width of signal, those are now the flash characteristics in time

↓

Loops over the hits

↓

Is this next hit within the stipulated time window to relate them?

- Yes → Continue to *space*
- No → Skip

Space

Grabs the center position (xyz) of the detector that got hit (and lies within the time window) and the center position of all other detectors that got hit

↓

Loops over the detectors

↓

Is the distance between these two within a window to relate them?

- Yes → Add to flash
- No → Skip

TDR simulations

May 2022 TDR analysis presentation:
https://indico.fnal.gov/event/54123/contributions/240389/attachments/154590/200947/vd_flash_finder_and_channel_saturation_studies.pdf

The idea is to verify the improvement of the new flash finder algorithm with respects to the old one, now with the data obtained during the August 2022 run, by making the same plots to compare.

New flash finder

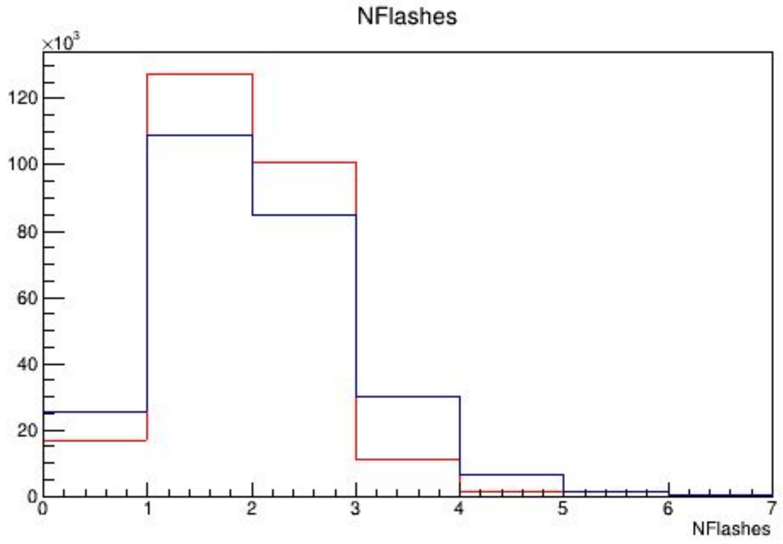
- Information from three detector planes as opposed to just one used before (cathode + two walls)

August simulation

- Generator: Marley (**ν**e), 5-30 MeV, no background
- 3 PD detector planes, Xe doping (Xe absorption length was increased from 20m to 80m from the May simulation)
- 6.5x13.5x21 m^{3} volume (particles were simulated within 9m in the z axis to account for long drifts)
- Reflectivity values were adjusted with respects to May simulation
- Field cage was included with respects to May simulation
- Events: 257751

RESULTS

#Flashes



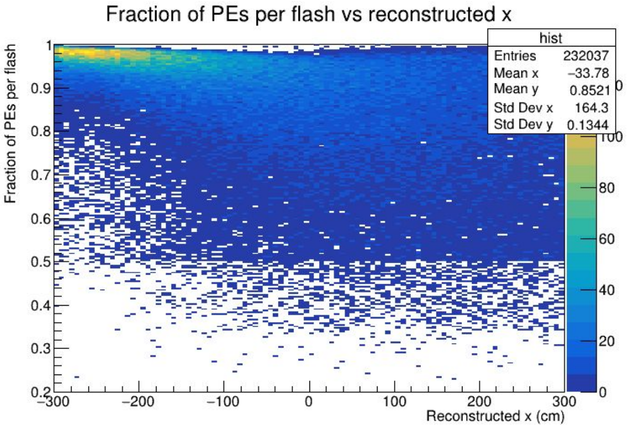
Here we have the difference between the amount of flashes created by the old analyzer (blue) with the new analyzer (red) for the August run. *Entries: 257751.*

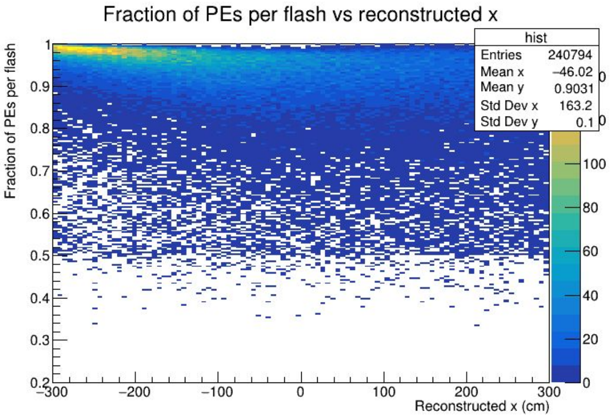
Obs:

a) Mean of #flashes changes from 1.567 to 1.431 (~9% decrease).

b) Amount of “0 flashes” (failure to create a flash) decreases from ~10% to ~6.6%.

PE fraction vs reconstructed x





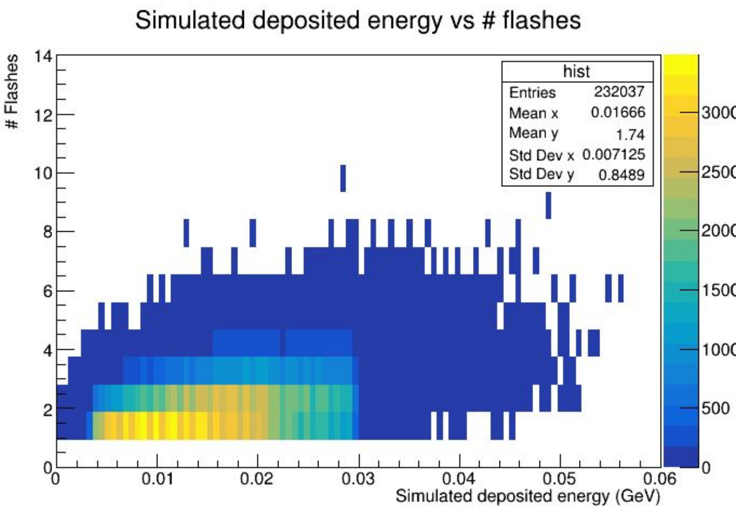
$$PE\,frac = \frac{PE_{largest\ flash}}{PE_{all\ flashes}}$$

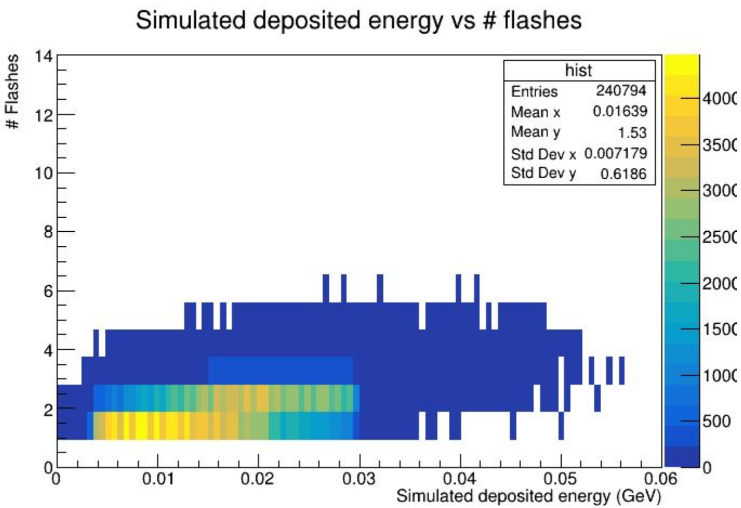
<u>Convention</u>: the left plot corresponds to the old flash finder, while the right one corresponds to the new algorithm

Like before, there's an improvement on the PEs fraction (0.85 to 0.90 →~6% increase), meaning that the clustering algorithm is improving.

<u>Obs:</u> the discrepancy between the entries of both histograms is due to the difference between the amount of 0 flashes previously showcased.

#flashes vs simulated deposited energy

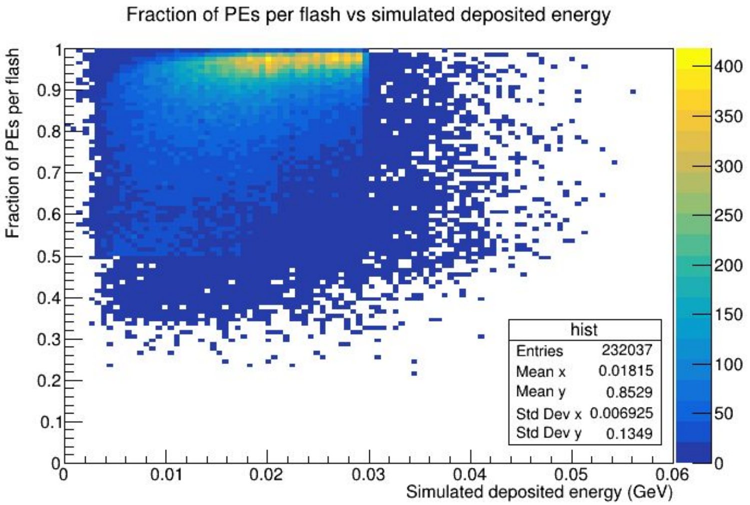


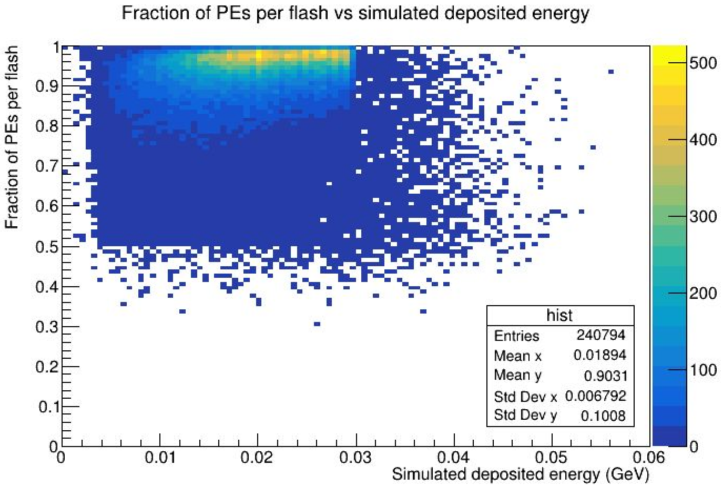


Comparison of the simulated deposited energy as a function of the amount of flashes. An improvement in the nflashes mean (1.74 to 1.53 → ~12% decrease) can be seen.

Obs: there seems to be a fair amount of flashes that have simulated deposited energies higher than the maximum energy originally simulated (30 MeV). This could be due to the interaction of neutrinos with the medium, generating charged particles that end up emitting light that is collected by the PDS.

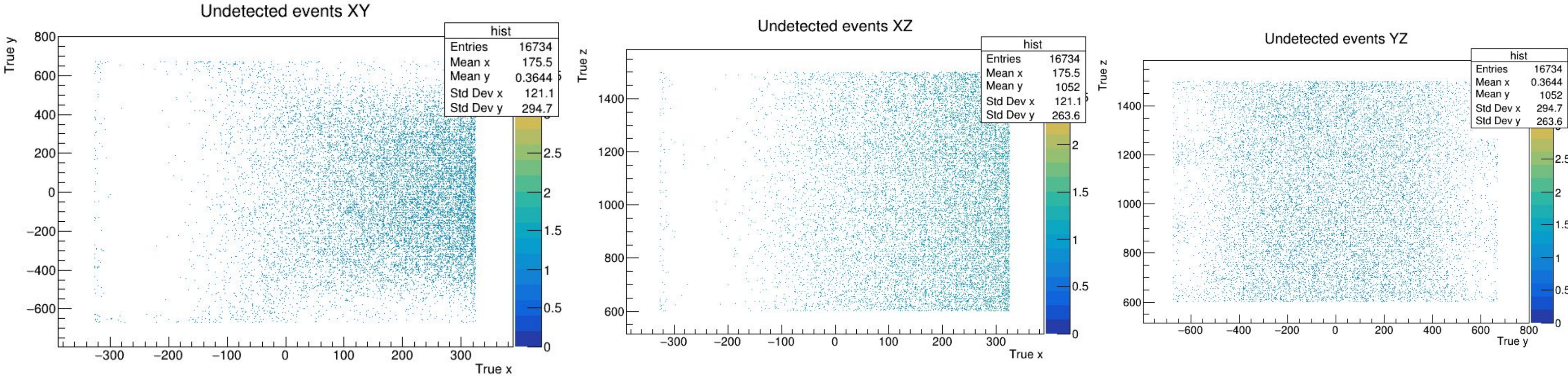
PE fraction vs simulated deposited energy





<u>Obs:</u> like in the previous slide, there seems to be a fair bit of flashes with energies higher than 30 MeV.

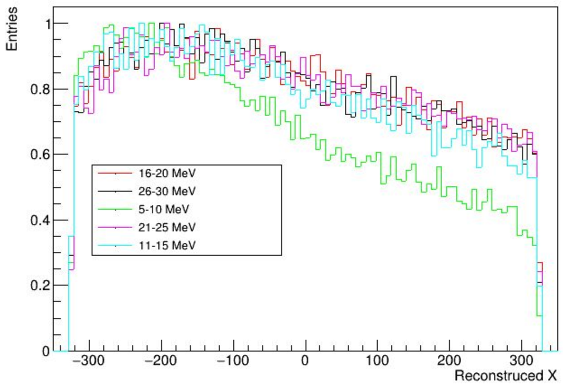
Undetected points

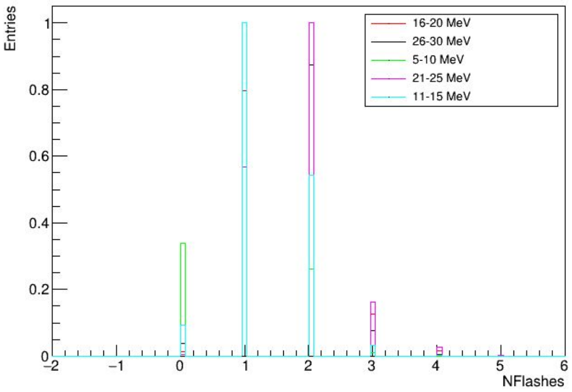


1) We can see that ~6.5% of the points were not able to be clustered.
2) The undetected points correspond to the positions further away from the cathode and membrane detectors.

Energy ranges comparison

Checking how is the algorithm’s performance for different energy ranges (low→high within the simulation). The energy ranges used were: 5-10 MeV, 11-15 MeV, 16-20 MeV, 21-25 MeV and 26-30 MeV.





Left: reconstructed X histogram for the energy ranges
Right: #flashes histogram for the energy ranges

1) We can see that the reconstruction is better in the cathode, and decrease as we move further away from it.
2) The lower energy range (5-10 MeV) appears to have a worse reconstruction than the other energy ranges. Even though this is reasonable, the question is: how much “worse” can it get before it has to be revisited, and for which energy values/ranges that happens?

Conclusions

1) The new flash finder algorithm shows an improvement in the clustering process. The mean of the #flashes sees a ~9% improvement, while the amount of failed clustering attempts is reduced by ~3.4%.
2) Particles with energies higher than 30 MeV are reconstructed, which could be due to the neutrino interaction with the medium.
3) Around 6.5% of the total events were not reconstructed, and these correspond mainly to the position further away from the cathode and the membrane detectors.
4) The lower energy neutrinos present a worse reconstruction →how low on energy can we reliably go to?
5) Background simulations have to be studied, as well as signal + background simulations